



PIER Energy-Related Environmental Research

Environmental Impacts of Energy Generation, Distribution and Use

Groundwater Contributions to Baseflow in the Merced River: Processes, Flow Paths, and Residence Times

Contract #: 500-02-004; UC MR-043-07

Contractor: University of California, Merced

Contract Amount: \$75,000

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The Issue

Information about baseflow is critical for reservoir operations and aquatic ecosystem management, both of which are part of hydroelectric generation planning and operations. Present knowledge of mountain-block hydrology¹ is insufficient for accurate estimation and modeling of the Sierra Nevada water balance, especially during dry years. As climate warming continues, it is urgent to improve our understanding of mountain-block hydrology and to provide better information to water resource and hydroelectric managers about the implications of likely climatic and hydrologic shifts. This project addresses that need by developing promising new scientific concepts concerning groundwater contributions to baseflow in the Merced River, a representative river draining the central and southern Sierra Nevada.



C. Marie Denn, National Park Service

The upper Merced River watershed encompasses approximately 114,840 acres (181.9 square miles) above Happy Isles in upper Yosemite Valley.

Project Description

The objectives of this project were to (1) understand the processes that link snowmelt and rainfall to mountain-block groundwater and baseflow, using established and innovative techniques, (2) estimate the contribution of mountain-block groundwater to baseflow, and (3) evaluate the impact of the change in snow quantity and timing of snowmelt on baseflow.

Funded by PIER's Environmental Exploratory Grants Program, the project integrated field, laboratory, and tracer-based modeling through a collaborative effort led by the University of California, Merced. Fieldwork was conducted in the Merced River from spring 2006 to 2007.

¹ Mountain-block hydrology is the hydrology for the entire mountain-block system, from the slope of the highest peak to the deepest recirculating groundwater. This study focuses on the water infiltrating the mountain block and discharging into the upper Merced River.

Groundwater residence times were determined using a radioactive isotope. Results for stable isotopes of the water molecule and specific conductivity were combined to determine the source waters of baseflow and to understand the links between snowmelt/rainwater and groundwater.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objective:

- **Provide reliable energy.** The new knowledge developed in this project will be of interest to water resource managers, hydroelectric managers, and environmental policy makers, as well as the broader scientific community. Direct benefit will go to the Federal Energy Regulatory Commission and the California Department of Water Resources, helping them plan hydroelectricity strategy for California, including dam relicensing.

Project Results

From August to October, 2006, baseflow in the Upper Merced River was primarily controlled by mountain-block groundwater, lateral subsurface flow, and overland flow, demonstrating a strong linkage between surface water and groundwater processes. The contribution of mountain-block groundwater increased from 10%–20% of the total streamflow discharge in August to over 50% in October. The mean residence time was estimated to be about 35 years for mountain-block groundwater and 20 years for some of the springs developed from or near the interface of soil and bedrock. Lateral subsurface flow dominated baseflow in August and September and accounted for more than 50% of the total streamflow. Overland flow primarily occurred at higher elevations above Happy Isles and accounted for less than 30% of the total streamflow.

Discharges (flow rates) of lateral subsurface flow and overland flow decreased gradually over time and were described using an exponential function. The timing of their contributions to the river was controlled by the snow quantity and timing of snowmelt. The response of lateral subsurface flow to snowmelt lagged two months behind the peak snowmelt, indicating that the mean travel time was about two months.

October baseflow at Happy Isles in the Upper Merced River has been significantly declining since 1984. The research team realizes that this decreasing trend is a response to the decrease in springtime snow water equivalent and the earlier onset of snowmelt occurring in the Sierra Nevada. Lateral subsurface flow is more sensitive to the change in snowmelt timing at higher elevations than at lower elevations. If the decline of snow water equivalent and the earlier onset of snowmelt continue as a result of climate change in the region, the decline in baseflow may expand to all autumn months and across the entire central and southern Sierra Nevada.

Final Report

The final report for this project can be downloaded from www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2007-116.

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